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*Report No. 05-15*

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## Self-Reported Reproductive Outcomes Among Male and Female 1991 Gulf War era US Military Veterans

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Received: 30 November 2005 / Accepted: 9 May 2006 / Published online: 11 July 2006  
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**Abstract** *Background:* Following the 1991 Gulf War, some veterans expressed concerns regarding their reproductive health. Our objective was to assess whether an association exists between deployment to the 1991 Gulf War and self-reported adverse pregnancy outcomes. *Methods:* Using a modified Dillman technique with telephone follow-up, we conducted a survey via a postal questionnaire from February 1996–August 1997 to compare selected reproductive outcomes among 10,000 US veterans deployed to the 1991 Gulf War with those of 10,000 nondeployed Gulf War era veterans. *Results:* A total of 8742 individuals responded to the survey, a response rate of 51 percent. Using multivariable analyses, results showed no differences in number of reported pregnancies between Gulf War veterans and nondeployed veterans. Among 2233 female and 2159 male participants, there were no differences in birth weight of infants born to

Gulf War veterans compared with nondeployed Gulf War era veterans. In multivariable models, male and female Gulf War veterans did not significantly differ in risk for ectopic pregnancies, stillbirths, or miscarriages when compared with nondeployed veterans of the same era. *Conclusions:* These results do not suggest an association between service in the 1991 Gulf War and adverse reproductive outcomes for both male and female veterans during the 4 years after the war.

**Keywords** Gulf War · Reproductive outcomes · Birth weight · Military

### Background

Since returning from the 1991 Gulf War, many veterans have reported diverse health problems they attribute to war exposures [1–4]. In response, numerous studies have described self-reported symptoms [5–12], hospitalizations [13–18], mortality [19–22], and specific wartime exposures [18, 23–26] in 1991 Gulf War veterans (GWVs). Due to at least 21 reproductive hazards known to be present in the Gulf War theater [27], veterans have also voiced concerns regarding their postwar reproductive health [28, 29] and, more specifically, about having children with birth defects [4]. Several epidemiological studies have been conducted to evaluate birth defects among children born to GWVs and their spouses [30–34], but currently, only a few studies have specifically evaluated infertility [35–37] or pregnancy outcomes of veterans after returning from the Gulf War [27, 38–40]. Results remain inconsistent when assessing the relationship between service in the 1991 Gulf War and adverse reproductive outcomes, and anecdotal reports persist suggesting some veterans may be at increased risk of reduced fertility, miscarriages, and

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genitourinary tract conditions [28]. The goal of this study was to utilize self-reported reproductive histories from both male and female GWVs and nondeployed veterans (NDVs) of the same era to assess the association between Gulf War service and adverse reproductive outcomes.

## Methods

### Study population

Demographic, military status, and Gulf War deployment status data for service members were obtained from the Defense Manpower Data Center (DMDC), Seaside, California, with missing information for age, race/ethnicity, and education backfilled using data from the survey. A GWV was considered an active duty, US Reserve, or National Guard military service member, between 18 and 33 years of age, who was assigned to the Gulf War theater of operations between August 1, 1990, and July 31, 1991. The theater of operations is the geographic area in which military operations are conducted; for the Gulf War, the theater included areas of Southwest Asia such as Iraq, Kuwait, the Persian Gulf, Arabian Sea, and airspace above these locations [41]. Military service members of the same era but not deployed to the Gulf War theater during the period August 1, 1990, to July 31, 1991 were defined as NDVs. Approximately 2.5 million male and 377,000 female active duty, Reserve, and National Guard service members were on the rosters in 1991, with approximately 644,000 men and 50,000 women deployed to the Gulf War theater of operations. To maximize reproductive activity, we included as potential study participants only married veterans who, according to DMDC, were married as of January 1, 1991 and still married in February, 1995, and were veterans between 18 and 33 years of age as of January 1, 1991. We assumed those who were married in 1991 and 1995 had been married to the same individual during that period, and all conceptions were with the same partner.

A sample size requirement of 16,000 was determined based on detecting a 10 percent difference in rates of miscarriages between GWVs and NDVs. The population rate for miscarriages was estimated at 10%, based on published data [12–14]. From GWV and NDV populations, a stratified random sample with equal-size sampling by gender, with proportionate allocation of service (US Army, Navy, Air Force, and Marine Corps) and component (active duty, Reserve, and National Guard) was generated. To allow for losses and oversampling of women, 10,000 men and 10,000 women were initially selected for study participation.

This study was conducted in accordance with the protection of human subjects guidelines of the US Department of the Navy and approved by the Naval Health Research

Center Institutional Review Board as NHRC Protocol Number 30276.

### Questionnaire

A four-page, self-completed postal questionnaire composed of multiple-choice and open-ended questions was developed. The questionnaire sought demographic data (race/ethnicity and educational attainment), information on military component and deployment status, and reproductive outcomes such as live births, birth weight, ectopic pregnancies, miscarriages/spontaneous abortions, and stillbirths. Standardized survey instruments were used in the questionnaire for comparability. Sources included the Chicago Reproductive Health Survey (National Institute of Environmental Health Sciences, Research Triangle Park, NC, 1991), the National Survey on Family Growth, Cycle IV [42], and the National Maternal and Infant Health Survey [43]. Miscarriages/spontaneous abortions were defined as fetal deaths occurring before 22 weeks gestation, while stillbirths were defined as fetal deaths occurring after 22 weeks gestation. Low birth weight (LBW) was defined as a live birth weighing <2500 g, and a macrosomic birth was defined as a birth weight  $\geq 4000$  g. Information on birth weight, gestational age, and infant's gender was sought for each live birth. Respondents completed separate entries for each outcome of a multiple birth.

### Data collection

#### *Questionnaire mailing process*

The target sample of 20,000 initial subjects was mailed a preliminary study notification letter in February 1996. Following a modified Dillman method [44], three rounds of questionnaires with reminder postcards were mailed over the next 18 months. Each mailing targeted individuals who had not responded to previous questionnaire mailings within the last 6 months. Study letterheads and logos were used on envelopes to distinguish study mailings. For potential participants on active duty, questionnaires were routed through commanding officers. For commanding officer attention, we attached letters from each service's surgeon general, stressing the study's importance and requesting support. For those no longer on active duty, cover letters with favorable comments from respondents about their perception of the study's significance and value were included. Addresses from DMDC were used for initial mailings. If questionnaires were returned as undeliverable, additional sources were used to identify valid current addresses, including military locator services, the Internal Revenue Service, and a commercial locator agency.

After the final mailing, 1042 male and 633 female participants were contacted by telephone to complete missing

information from submitted questionnaires. Five attempts to establish telephone contact were made, between 9 AM and 5 PM in the individual's time zone, before being classified as "unreachable." Missing data were obtained for 66% (687/1042) of male and 66% (418/633) of female participants. Data could not be obtained from the remaining 570 individuals, including 65 women and 107 men who refused to provide information on missing data over the telephone, or could not be interviewed at an apparently correct telephone number.

### Statistical analysis

After descriptive investigation of population characteristics, analyses were performed to assess the significance of associations between the odds of reporting any pregnancy and Gulf War status, and in a separate model, the odds of reporting any adverse pregnancy outcome and Gulf War status. Both models were stratified by gender, and adjusted for prior adverse reproductive outcome, age, race/ethnicity, educational level, rank, service, component, and occupation. Logistic regression modeling was employed to compare adverse reproductive outcomes among GWVs and NDVs, and stratified by gender. Analyses of adverse reproductive outcomes were limited to female and male respondents who reported a live birth, miscarriage, stillbirth, or ectopic pregnancy. Singleton and multiple birth outcomes were analyzed separately. Odds ratios were adjusted for mother's age as of July 31, 1991 (ages 17–24, 25–29, or  $\geq 30$ ), service branch (Army, Navy, Air Force, or Marine Corps), race/ethnicity (White non-Hispanic, Black non-Hispanic, or other), highest level of education attained (high school or less, some college, post-graduate, or unknown), occupation (combat or other), and pre-1991 reproductive outcomes. As in previous studies [13, 15, 16, 23, 25, 26, 45], a pre-deployment indicator for adverse reproductive outcomes was created. Predeployment adverse outcomes included any miscarriage, ectopic pregnancy, or stillbirth as reported on the questionnaire, or hospitalization for any condition listed under the category of Complications of Pregnancy, Childbirth, and the Puerperium (*International Classification of Diseases, 9th Revision, Clinical Modification*, codes 630–676) as recorded at Department of Defense (DoD) medical facilities between August 1, 1989, and July 31, 1990. Generalized estimating equations were used to study the effect produced by correlated adverse reproductive outcomes from the same respondent on multivariable estimates [46]. Estimates produced using GEEs were not appreciably different from those produced using multivariable logistic regression. For this reason, we utilized multivariable logistic regression models to calculate adjusted estimates for all self-reported adverse reproductive outcomes occurring during the study period, January 1, 1991, to December 31, 1995. All statistical analyses were conducted using SAS®

software (Version 9.1, SAS Institute, Inc., Cary, North Carolina) [47].

## Results

Of the 20,000 individuals originally selected for participation, 17,140 with valid addresses were contacted, and 8742 responded (51.0%). Mean duration of deployment did not differ significantly between GWV respondents and GWV nonresponders (mean, 155.0 days; standard deviation [SD], 73.9 days and mean, 155.0 days; SD, 71.3 days, respectively). Descriptive analyses for GWVs show that responders were significantly older, proportionately more white, non-Hispanic, college educated, officers, and members of the Navy or Air Force. While results for 8567 NDVs were generally similar to those for GWVs, NDV responders were significantly more likely to be women and members of the active duty force rather than Guard or Reserve (Table 1). Although response among GWVs was not influenced by presence of adverse reproductive outcomes prior to the Gulf War ( $p = 0.340$ ), NDV response appears to have been influenced by previous adverse reproductive outcomes ( $p = 0.023$ ).

Multivariable logistic regression ( $n = 8734$ ; 99.9% complete) was used to calculate adjusted odds ratios for any pregnancy stratified by gender, adjusting simultaneously for Gulf War status, prior adverse pregnancy outcome, mother's age, race/ethnicity, education level, rank, service branch, component, and occupation (Table 2). There were no differences in the number of self-reported pregnancies between the GWV and NDV groups for both male and female respondents (adjusted odds ratio [OR], 1.00; 95% confidence interval [CI], 0.88–1.14 and adjusted OR, 0.92; 95% CI, 0.81–1.06, respectively). Among male respondents, the odds of reporting any pregnancy was significantly higher for those who had a prior adverse pregnancy outcome, were officers or warrant officers, as well as members of the Navy and Marine Corps. Similarly, women were at significantly higher odds for any pregnancy when they reported a prior adverse pregnancy outcome, or were officers or warrant officers. As expected, men and women in the highest age group, 30 years and older, were significantly less likely to report a pregnancy than were men and women in the youngest age group.

The subset of 2159 men and 2233 women who had reported one or more pregnancies were further analyzed (Table 3). The percentage of men and women reporting any adverse pregnancy outcomes was similar (16.4% and 18.6%, respectively) and there were no differences in risk for any adverse pregnancy outcome based on Gulf War status for men (adjusted OR, 1.23; 95% CI, 0.96–1.56) or women (adjusted OR, 1.16; 95% CI, 0.91–1.48) after adjusting for gender,

**Table 1** Characteristics of 8742 responders and 8398 nonresponders, adverse reproductive outcomes among Gulf War veterans and nondeployed veterans, 1991–1995

	Gulf War Veteran			Nondeployed Veteran		
	Responder n <sup>a</sup> (%)	Nonresponder n <sup>a</sup> (%)	P value <sup>b</sup>	Responder n <sup>a</sup> (%)	Nonresponder n <sup>a</sup> (%)	P value <sup>b</sup>
<b>Gender</b>						
Male	2209 (49)	2245 (50)	.033	2201 (49)	2252 (50)	.001
Female	2938 (51)	1981 (48)		2394 (53)	1920 (46)	
<b>Age group, y<sup>c</sup></b>						
≤ 24	1299 (45)	1897 (54)	.001	1207 (45)	1587 (54)	.001
25–29	1954 (52)	1470 (47)		1627 (52)	1469 (47)	
≥ 30	1092 (55)	1059 (45)		1761 (56)	1316 (43)	
<b>Race/ethnicity</b>						
White, non-Hispanic	2964 (55)	2683 (44)	.001	3809 (55)	2659 (44)	.001
Black, non-Hispanic	1028 (41)	1653 (58)		757 (39)	1140 (60)	
Other	382 (47)	384 (52)		329 (47)	370 (52)	
<b>Highest educational level</b>						
High school, or less	2547 (47)	2818 (52)	.001	2535 (47)	2799 (52)	.001
College/postgraduate	1503 (61)	690 (38)		1962 (59)	1112 (40)	
<b>Rank</b>						
Enlisted	3765 (48)	3941 (51)	.001	3393 (49)	3795 (50)	.001
Officer/Warrant	582 (67)	285 (32)		702 (65)	377 (34)	
<b>Service branch</b>						
Army	2556 (47)	2607 (52)	.001	1175 (43)	1813 (56)	.001
Navy	810 (53)	794 (46)		1294 (55)	1640 (44)	
Air Force	280 (60)	427 (39)		1154 (55)	1929 (44)	
Marine Corps	471 (50)	438 (49)		272 (48)	290 (51)	
<b>Service component</b>						
Active duty	3009 (51)	3557 (49)	.0137	4827 (51)	3935 (48)	.001
Guard/Reserve	638 (48)	639 (51)		158 (41)	257 (58)	
<b>Occupational codes</b>						
Other than combat	3736 (50)	3315 (49)	.0594	3835 (51)	3571 (48)	.0025
Combat	601 (50)	601 (50)		530 (48)	681 (51)	
<b>Pre-Gulf War adverse pregnancy outcome</b>						
Yes	167 (53)	166 (46)	.0840	263 (56)	186 (43)	.0023
No	4680 (50)	4080 (49)		4052 (51)	3986 (49)	

<sup>a</sup>Frequency of missing values: (1) Responders; age = 2, race/ethnicity = 3, education = 895; (2) Nonresponders; race/ethnicity = 9, education = 979

<sup>b</sup>Tests of statistical significance were based on two-tailed Person chi-square test

<sup>c</sup>Maternal age

mother's age, race/ethnicity, education, rank, service branch, component, and occupation. Among men, members of the Navy and Air Force were significantly less likely to have any adverse reproductive outcome, compared with members of the Army, while among women, black, non-Hispanics were at significantly increased risk for any adverse reproductive outcome in comparison with white, non-Hispanics (adjusted OR, 1.45; 95% CI, 1.13–1.86).

Women reported a total of 470 reproductive losses. Thirty-four (2 stillbirths, 6 ectopic pregnancies, and 26 miscarriages) were identified as multiple events. Similarly, men reported a total of 397 reproductive losses, with 32 being repetitive events (5 stillbirths, 8 ectopic pregnancies, and 19 miscarriages). In separate multivariable logistic regression

models that calculated the adjusted odds based upon multiple, correlated outcomes, male and female GWVs were not at significantly increased odds for miscarriages, stillbirths, or ectopic pregnancies (Table 4). Nor were male and female GWVs at significantly increased odds for outcomes associated with birth weight (Table 5). All models were adjusted for prior adverse pregnancy outcome, mother's age, race/ethnicity, education level, rank, service branch, component, and occupation.

Female respondents reported 36 twin births (13.3/1000 live births) and male respondents reported 21 twin births (8.8/1000 live births) post-Gulf War. The differences in twin births for male and female respondents were not statistically significant ( $p = 0.07$ ). No triplet or higher-order births were

**Table 2** Multivariable logistic regression of veterans reporting and not reporting pregnancy, by gender, 1991–1995

	Men			Women		
	Any reported contribution to pregnancy?			Any reported pregnancy?		
	Yes n (%)	No n (%)	OR <sup>a</sup> (95% CI)	Yes n (%)	No n (%)	OR <sup>a</sup> (95% CI)
<b>Gulf War status</b>						
Gulf War veteran	1083 (50)	1921 (49)	1.00 (0.88,1.14)	1070 (47)	1865 (50)	0.92 (0.81,1.06)
Nondeployed veteran <sup>b</sup>	1076 (49)	1125 (50)		1163 (52)	1231 (49)	
<b>Prior adverse pregnancy outcome</b>						
Yes	98 (4)	100	112.05 (15.56,806.95)	302 (14)	196 (7)	2.05 (1.67,2.51)
No <sup>c</sup>	2066 (95)	2045 (100)		1911 (85)	1930 (92)	
<b>Age group, y<sup>c</sup></b>						
≤ 24 <sup>b</sup>	758 (35)	521 (23)		903 (40)	525 (25)	
25–29	890 (41)	768 (34)	0.73 (0.62,0.85)	855 (38)	747 (35)	0.60 (0.51,0.70)
≥ 30	571 (23)	927 (42)	0.33 (0.28,0.39)	465 (20)	824 (39)	0.29 (0.24,0.34)
<b>Race/ethnicity</b>						
Black, non-Hispanic	295 (13)	390 (17)	0.85 (0.71,1.01)	537 (24)	562 (26)	0.98 (0.84,1.14)
Other	115 (8)	172 (7)	1.14 (0.91,1.44)	124 (8)	149 (7)	1.20 (0.94,1.52)
White, non-Hispanic <sup>b</sup>	1689 (78)	1084 (75)		1512 (67)	1385 (66)	
<b>Highest educational level</b>						
College/postgraduate	754 (34)	790 (35)	1.01 (0.85,1.20)	974 (43)	998 (47)	1.07 (0.91,1.26)
High school or less <sup>b</sup>	1105 (65)	1856 (64)		1259 (56)	1498 (52)	
<b>Rank</b>						
Officer	383 (15)	261 (11)	1.63 (1.30,2.04)	387 (17)	303 (14)	1.67 (1.36,2.03)
Enlisted <sup>b</sup>	1626 (84)	1985 (88)		1746 (82)	1593 (85)	
<b>Service branch</b>						
Navy	620 (28)	620 (27)	1.18 (1.00,1.39)	456 (20)	406 (19)	1.09 (0.91,1.31)
Air Force	582 (27)	622 (27)	1.16 (0.97,1.38)	671 (30)	659 (29)	1.00 (0.85,1.17)
Marine Corps	281 (13)	224 (10)	1.30 (1.05,1.61)	165 (5)	83 (4)	1.28 (0.94,1.74)
Army <sup>b</sup>	676 (31)	780 (34)		981 (43)	988 (47)	
<b>Service component</b>						
Active duty	2034 (94)	2114 (94)	0.90 (0.68,1.19)	1496 (89)	1571 (85)	1.21 (0.98,1.49)
Guard/Reserve <sup>b</sup>	125 (5)	192 (5)		267 (10)	305 (14)	
<b>Occupational codes</b>						
Combat	529 (24)	459 (20)	1.14 (0.98,1.33)	924 (4)	914 (4)	0.81 (0.59,1.10)
Other than combat <sup>b</sup>	1630 (75)	1687 (79)		2941 (95)	2005 (95)	

<sup>a</sup>Adjusted odds ratio and 95% confidence interval<sup>b</sup>Reference group<sup>c</sup>Maternal age

reported, and there was no statistically significant association between Gulf War deployment and twin/multiple births (females: OR, 0.89, 95% CI, 0.54–1.47; males: OR, 0.85, 95% CI, 0.47–1.55) (data not shown).

## Discussion

During the four years after the war, we found no evidence that male or female GWVs were at significantly increased odds for adverse reproductive outcomes. We also observed no statistically significant differences in birth weight of infants born to GWVs and NDVs. Finding no statistically significant increased odds for miscarriages among male GWVs contrasts with previous papers reporting modest but statistically significant increased risk for miscarriages among this

group [38, 48], as well as men serving in Vietnam [49]. Additionally, we found no evidence to support a 1999 report that male service members fathered pregnancies that more often resulted in miscarriage [50]. Finding no increased risk for adverse reproductive outcomes among female GWVs is consistent with other population-based studies of Gulf War service members from the United States and the United Kingdom [38, 48]. Increased risk for miscarriage and ectopic pregnancy among female GWVs has been reported in one study that used a small, hospital-based cohort [39].

In multivariable modeling, age was not significantly associated with adverse reproductive outcomes for men or women; however, black, non-Hispanic women were significantly associated with increased odds for an adverse reproductive outcome in comparison with white, non-Hispanic

**Table 3** Multivariable logistic regression of veterans reporting and not reporting adverse pregnancy outcomes, 1991–1995

	Men			Women		
	Any reported adverse pregnancy outcome?		OR <sup>a</sup> (95% CI)	Any reported adverse pregnancy outcome?		OR <sup>a</sup> (95% CI)
	Yes n (%)	No n (%)		Yes n (%)	No n (%)	
<b>Gulf War status</b>						
Gulf War veteran	197 (55)	886 (49)	1.23 (0.96,1.56)	248 (52)	852 (46)	1.16 (0.91,1.48)
Nondeployed veteran <sup>b</sup>	157 (44)	919 (50)		198 (47)	905 (53)	
<b>Prior adverse pregnancy outcome</b>						
Yes	18 (4)	26 (4)	1.12 (0.65,1.93)	62 (14)	260 (14)	1.03 (0.76,1.40)
No <sup>b</sup>	327 (95)	1729 (95)		354 (85)	1557 (85)	
<b>Age group, y<sup>c</sup></b>						
≤ 24 <sup>b</sup>	186 (32)	662 (35)		165 (39)	588 (40)	
25–29	157 (41)	723 (41)	1.13 (0.85,1.49)	154 (37)	701 (39)	0.99 (0.77,1.28)
≥ 30	91 (25)	420 (23)	1.23 (0.89,1.70)	95 (23)	398 (20)	1.22 (0.90,1.66)
<b>Race/ethnicity</b>						
Black, non-Hispanic	56 (15)	239 (13)	1.12 (0.81,1.55)	130 (31)	407 (22)	1.45 (1.13,1.86)
Other	29 (7)	139 (8)	0.89 (0.57,1.38)	29 (5)	180 (8)	0.70 (0.44,1.09)
White, non-Hispanic <sup>b</sup>	282 (76)	1517 (78)		262 (63)	1250 (68)	
<b>Highest educational level</b>						
College/postgraduate	104 (35)	680 (34)	1.05 (0.76,1.46)	185 (44)	789 (43)	1.12 (0.85,1.49)
High school or less <sup>b</sup>	280 (65)	1175 (65)		251 (55)	1028 (56)	
<b>Rank</b>						
Officer	56 (15)	207 (15)	0.99 (0.66,1.49)	58 (13)	329 (18)	0.71 (0.50,1.01)
Enlisted <sup>b</sup>	228 (84)	1528 (84)		358 (86)	1988 (81)	
<b>Service branch</b>						
Navy	88 (24)	552 (29)	0.69 (0.50,0.93)	87 (20)	370 (20)	1.06 (0.78,1.44)
Air Force	82 (23)	570 (27)	0.68 (0.49,0.93)	192 (26)	559 (30)	0.91 (0.68,1.21)
Marine Corps	54 (14)	230 (12)	0.92 (0.64,1.33)	19 (4)	186 (5)	0.78 (0.46,1.31)
Army <sup>b</sup>	163 (37)	543 (30)		189 (47)	782 (43)	
<b>Service component</b>						
Active duty	355 (94)	1699 (94)	1.35 (0.79,2.33)	361 (86)	1035 (90)	0.82 (0.57,1.18)
Guard/Reserve <sup>b</sup>	14 (5)	196 (5)		25 (13)	182 (10)	
<b>Occupational codes</b>						
Combat	85 (24)	464 (24)	0.89 (0.67,1.17)	14 (3)	78 (4)	0.88 (0.49,1.60)
Other than combat <sup>b</sup>	209 (76)	1361 (75)		462 (96)	1739 (95)	

<sup>a</sup>Adjusted odds ratio and 95% confidence interval<sup>b</sup>Reference group<sup>c</sup>Maternal age**Table 4** Multivariable logistic regression of adverse pregnancy outcomes for male and female Gulf War veterans and nondeployed veterans, 1991–1995

	Adverse pregnancy outcome					
	Miscarriage		Stillbirth		Ectopic pregnancy	
	n	OR <sup>a</sup> (95% CI)	n	OR <sup>a</sup> (95% CI)	n	OR <sup>a</sup> (95% CI)
<b>Men</b>						
Gulf War veteran	176	1.24 (0.96, 1.61)	14	0.96 (0.40, 2.31)	27	1.09 (0.58, 2.04)
Nondeployed veteran <sup>b</sup>	143		12		25	
<b>Women</b>						
Gulf War veteran	191	1.14 (0.87, 1.48)	14	1.58 (0.63, 3.95)	38	0.99 (0.58, 1.67)
Nondeployed veteran <sup>b</sup>	185		8		34	

<sup>a</sup>Reference group<sup>b</sup>Adjusted odds ratio and 95% confidence interval

women. This finding has been thoroughly documented in the US civilian population [51–53], and because we assume equal access to prenatal care among all active duty families, the observed modest association (adjusted OR, 1.45; 95% CI, 1.13–1.86), may reflect other pregnancy-related

differences between black non-Hispanic women and white non-Hispanic women of approximately equal reproductive age, such as differences in obesity, hypertension, and diabetes [53–57]. A previous study utilized adult, married military members living in Hawaii and birth records to examine

**Table 5** Multivariable logistic regression of birth weight of infants born to male and female Gulf War veterans and nondeployed veterans, 1991–1995

		Birth weight					
		Microsomia <sup>a</sup>		Normal		Macrosomia <sup>b</sup>	
		n	OR <sup>c</sup> (95% CI)	n	OR <sup>c</sup> (95% CI)	n	OR <sup>c</sup> (95% CI)
<b>Men</b>							
Gulf War veteran	73	1.21 (0.81, 1.82)	988	0.95 (0.79, 1.15)	158	0.91 (0.70, 1.19)	
Nondeployed veteran <sup>d</sup>	58		996		175		
<b>Women</b>							
Gulf War veteran	83	1.10 (0.71, 1.70)	1027	0.89 (0.73, 1.09)	139	1.09 (0.81, 1.46)	
Nondeployed veteran <sup>d</sup>	70		1138		166		

<sup>a</sup>Microsomia births are <2500 g<sup>b</sup>Macrosomia births are ≥4000 g<sup>c</sup>Adjusted odds ratio and 95% confidence interval<sup>d</sup>Reference group

race/ethnicity differences in pregnancy outcomes [58]. After adjusting for available socioeconomic characteristics, black women remained at risk of delivering a low birthweight infant in comparison to white women. Further studies to explore differences in reproductive outcomes among various races and ethnic groups within members of the US military, who theoretically have equal access to prenatal care, remain of value to understand fundamental relationships between race/ethnicity and adverse reproductive outcomes. The DoD Center for Deployment Health Research has several on-going efforts that may provide further insight into adverse reproductive outcomes including the Millennium Cohort Study [59] and the DoD Birth and Infant Health Registry [60].

Consistent with findings from Vietnam-era veterans [61], results from our analyses of singleton live births found no evidence to suggest GWVs are at increased risk for having abnormal birth weight infants. According to the Centers for Disease Control and Prevention, 7.1% of all births occurring in 1991 met the definition for LBW (<2500 g), increasing slightly to 7.3% by 1995 [62]. In our study, male NDVs reported 5% of births met the LBW definition, which meets the Healthy People 2010 goal of 5% [63]. Male GWVs reported 6.4% of births meeting the definition of LBW; although this is the highest of the four groups in this study, it still falls below the 1995 national average of 7.3% noted above. Finding a lower than expected number of low-weight births may reflect increased availability of prenatal care for US military personnel and their families, or more likely reflects a healthier and younger population than the entire US population of mothers giving birth.

We observed rates for twins above those nationally reported. According to the National Center for Health Statistics, twin births rose 11% during the 1990s and 42% between 1980 and 1997, with substantial increases in mothers who were 45–49 years of age, and reported to be 100 times more likely to give birth to twins than were teenage mothers

[64]. Additionally, during this period, the differences in twin birth rates between white and black non-Hispanic women declined. During 1980, twins represented 18.1 and 24.0 per 1,000 live births, respectively and 28.8 and 30.0 per 1,000 respectively in 1997. The trend for increased rate of twin pregnancies was noted to parallel national trends for older age at childbirth and increased use of fertility-enhancing drugs. It is likely that any observed differences in twin births between our study and national rates are due to either demographic differences in age, race/ethnicity, or differences in the use of fertility-enhancing drugs.

This study had a number of strengths. We believe this is the first study of 1991 Gulf War veterans to report infant birthweight analyses, and finding no significant differences with the general population is comforting. Although response bias is always a concern when using self-reported data, it appears to be minimal in that approximately equal numbers of GWVs and NDVs that were representative of the sampling population completed the postal questionnaire. To our knowledge, this study contains one of the largest samples of female GWVs. A total of 4332 women participated in the study, of which 2135 GWV women with 1070 pregnancies were used in the multivariable analyses. Finally, a robust analytic method was employed that utilized all available pregnancies, and measures were taken to ensure the correlation between multiple outcomes from the same participant were assessed. This allowed each pregnancy to contribute to study findings, yet overcame challenges due to the statistical correlations between multiple pregnancies among respondents.

Study findings must be interpreted within the context of possible limitations inherent when analyzing self-reported adverse reproductive outcomes. Recall bias may adversely affect any study that utilizes self-reported information and generally causes risk estimates to be inflated. However, because we observed no statistically significantly positive associations, the probability of significant recall bias

**Table 6** Race and ethnicity distribution comparison of all deployed and nondeployed US service members compared to deployed and nondeployed participants of adverse reproductive outcomes study

	Gulf War Cohort		Study Cohort	
	Deployed (%)	Nondeployed (%)	Deployed (%)	Nondeployed (%)
White	70	72	68	75
Black	22	21	23	17
Other	6	6	8	5

influencing study findings is low. Poor response may cause study participants to be dissimilar in comparison with the population of interest. For both GWVs and NDVs, responders tended to be older, thus we would expect to observe proportionately more adverse pregnancy outcomes in our responders due to age differences. We would also anticipate that the differential response observed for previous adverse pregnancy outcomes among NDVs would likely contribute to reduce any true effect associated with Gulf War service. Conversely, GWV and NDV responders tended to be white non-Hispanic while GWV and NDV non-responders were more likely to be black non-Hispanic, which would likely reduce the proportion of adverse outcomes in the participants versus non-participants. However, when we compared the proportional distribution of race/ethnicity by Gulf War service status to published data [65], we were quite comparable (Table 6). It is difficult to predict how these differences in response may have ultimately affected study findings. Self-reported adverse pregnancy outcomes were not confirmed by medical records review, thus we were unable to assess differential reporting between GWVs and NDVs. Both male and female GWVs were at non-statistically significant increased odds for any adverse reproductive outcome indicating a potential for reporting or recall bias. However, the magnitude of these positive findings is minimal indicating that any bias attributable to either reporting or recall differences between GWVs and NDVs did not contribute significantly to type I error. Finally, information was not collected on maternal risk factors, such as obesity, diabetes, or hypertension, and this may have affected results, if response was differential for GWVs and NDVs based upon maternal risk factors.

## Conclusions

Our findings suggest that deployment to the Persian Gulf region during the 1991 Gulf War is not associated with increased odds of adverse pregnancy outcomes. Furthermore, Gulf War deployment was not associated with low or macrosomic birth weight. Further research is needed to more objectively assess the potential effect of deployment exposures on reproductive health. Acting on concerns raised after the 1991 Gulf War, the DoD has recognized this need, and established the Millennium Cohort Study, a 21-year prospective cohort study of military personnel [66], and the DoD Birth

and Infant Health Registry [67], which provides systematic surveillance of DoD family births. These projects will enable the US military to better assess reproductive health outcomes in the military and may lead to important health policy implications for veterans returning from current deployments to the Persian Gulf region.

**Acknowledgments** The authors gratefully acknowledge the support of the following professionals: Dr. Gary Gackstetter, Dr. Tomoko Hooper, Dr. Karl Friedl, Robert J. Reed, Andrew Zau, Dr. Rebecca Calderon, Michael A. Dove from the Defense Manpower Data Center, and the Henry M. Jackson Foundation for the Advancement of Military Medicine. This represents report 05-15, supported by the Department of Defense, under work unit no. 60002. The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Navy, Department of the Air Force, Department of Defense, or the US Government. Approved for public release; distribution is unlimited. This research has been conducted in compliance with all applicable Federal Regulations governing the protection of human subjects in research (Protocol # 30276).

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1. Report Date (DD MM YY)	2. Report Type		3. DATES COVERED (from - to)		
14 July 2005	New		1991 - Present		
4. TITLE AND SUBTITLE Self-Reported Reproductive Outcomes Among Male and Female 1991 Gulf War Era US Military Veterans			5a. Contract Number: 5b. Grant Number: 5c. Program Element: 5d. Project Number: 5e. Task Number: 5f. Work Unit Number: 20006		
6. AUTHORS Timothy S. Wells, DVM, PhD; Linda Z. Wang, BS; Christina N. Spooner, MS; Tyler C. Smith, MS; Katia M. Hiliopoulos, MPH, MBA; Deborah R. Kamens, MBA; Gregory C. Gray, MD, MPH; Paul A. Sato, MD			9. PERFORMING ORGANIZATION REPORT NUMBER Report No. 05-15		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Health Research Center P.O. Box 85122 San Diego, CA 92186-5122					
8. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES) Chief, Bureau of Medicine and Surgery Code M53 2300 E St NW Washington DC 20372-5300			10. Sponsor/Monitor's Acronym(s) DOD		
			11. Sponsor/Monitor's Report Number(s)		
12 DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.					
13. SUPPLEMENTARY NOTES Published in <u>Maternal Child Health Journal</u> , 2006, 10, 501-510					
14. ABSTRACT (maximum 200 words)  <b>Background:</b> Following the 1991 Gulf War, some veterans expressed concerns regarding their reproductive health. Our objective was to assess whether an association exists between deployment to the 1991 Gulf War and self-reported adverse pregnancy outcomes. <b>Methods:</b> Using a modified Dillman technique with telephone follow-up, we conducted a survey via a postal questionnaire from February 1996 – August 1997 to compare selected reproductive outcomes among 10,000 US veterans deployed to the 1991 Gulf War with those of 10,000 nondeployed Gulf War era veterans. <b>Results:</b> A total of 8742 individuals responded to the survey. Using multivariable analyses, results showed no differences in number of reported pregnancies between Gulf War veterans and nondeployed veterans. Among 2233 female and 2159 male participants, there were no differences in birth weight of infants born to Gulf War veterans compared with nondeployed Gulf War era veterans. In multivariable models, male and female Gulf War veterans did not significantly differ in risk for ectopic pregnancies, stillbirths, and miscarriages when compared with nondeployed veterans of the same era. <b>Conclusions:</b> These results do not suggest an association between service in the 1991 Gulf War and adverse reproductive outcomes for both male and female veterans during the 4 years after the war.					
15. SUBJECT TERMS reproductive medicine, military medicine, military personnel, veterans					
16. SECURITY CLASSIFICATION OF: a. REPORT UNCL		b. ABSTRACT UNCL	c. THIS PAGE UNCL	17. LIMITATION OF ABSTRACT UNCL	18. NUMBER OF PAGES 10
19a. NAME OF RESPONSIBLE PERSON Commanding Officer					
19b. TELEPHONE NUMBER (INCLUDING AREA CODE) COMM/DSN: (619) 553-8429					